Apr 28th, 12:00 AM - 12:00 AM

Chemical Composition and Source Regions of Dry Deposition

Rudi Randall

Chemical composition and source regions of dry deposition

Rudi Randall and Dr. Derek Straub

Department of Earth and Environmental Science | Susquehanna University, Selinsgrove, PA

Background

Atmospheric pollutants can be removed through either wet deposition (particles and gases mixing with precipitation before reaching the surface) or dry deposition (dry particles and gases reaching the surface, Figure 1). Despite this, wet deposition is studied more regularly and in-depth than dry deposition. In this research, dry deposition to a wet surface was studied through the collection of dew and frost and measurement of their concentrations of anions, cations, and organic acids. To determine source regions of the chemicals found, back trajectories were created through modeling. Comparisons between dry and wet deposition fluxes were made using data from the National Atmospheric Deposition Program. Dew deposition was also compared to historical dew studies to examine changes over time. Combined, this provides a well-rounded understanding of dry deposition's role in removing air pollutants.

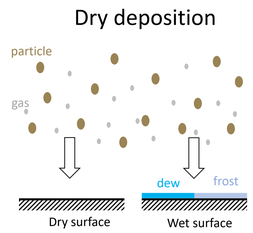

Figure 1: Diagram showing the processes of dry deposition to dry and wet surfaces.

Methods

- The sampling site was in a grassy lawn behind the Natural Sciences Center at Susquehanna University in Selinsgrove, PA (40.7973 N 76.8745 W).
- Dew and frost samples were collected on a 0.84 m^2 Teflon-covered surface (Figure 2a). It was clamped onto a table around dusk. Before sunrise, any dew or frost on the surface would get collected for lab analysis.
- Lab analysis included measurements of pH and liquid mass plus ion chromatography (IC) (Figure 2b).
- After collecting samples, the collection surface was cleaned with deionized water. Once the collector was clean, a blank sample was taken and used to calculate limits of detection for each chemical (Figures 3a and 3b).
- The HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model was used to create back trajectories of airmass travel three days prior to collection of each sample.
- Weekly wet deposition data from the National Atmospheric Deposition Program (NADP) were used for comparison to dry deposition samples.

Figure 2: Collector used for this research (a) and the ion chromatograph used to analyze deposition chemical makeup (b).

Data and Figures

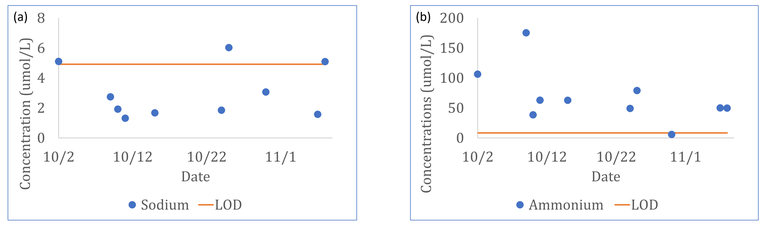

Figure 3. Concentrations (µmol/L) of sodium (a) and ammonium (b) from each sample were compared to their limits of detection (LOD) . The limit of detection was calculated to discern "reliable" data from "unreliable" data, with reliable data being above the LOD.

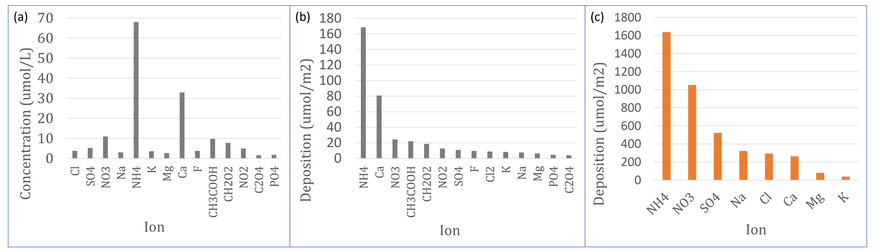

Figure 4. Concentrations of ions and organic acids (µmol/L) (a) were averaged and converted into deposition values (µmol/m^2) to assess the total amount deposited on the collector area (b). Wet deposition data from the NADP was also converted to these units for comparison purposes (c).

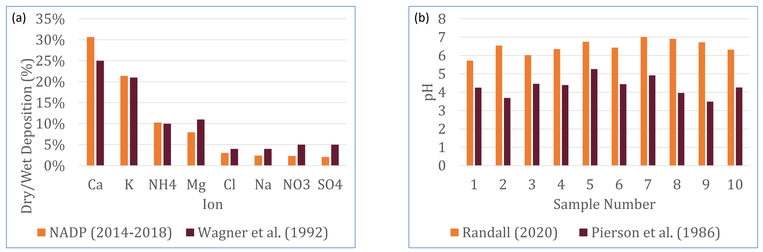

Figure 5. A ratio of dry deposition (this study) to wet deposition data (NADP) was compared to ratios calculated by Wagner et al. (1992) (a). Historical dew pH data from Pierson et al. (1986) were compared to dew pH from this research (b).

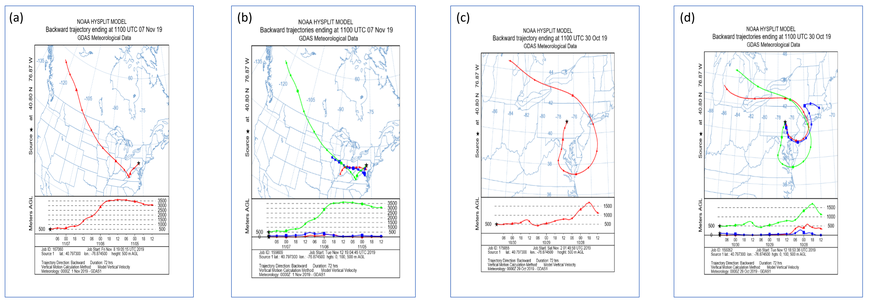

Figure 6. HYSPLIT trajectories for the 72 hours prior to collection of samples. Figures (a) and (c) depict trajectories at a single height (500 meters AGL) while Figures (b) and (d) depict those trajectories at three heights (0 m AGL in red, 100 m AGL in green, and 500 m AGL in blue) over the same timespan. Figures (a) and (b) show a "backwards check" trajectory while Figures (c) and (d) show a trajectory that partially travels over the Atlantic Ocean.

Results and Discussion

Ten samples of dry deposition onto a liquid or icy surface were collected over five weeks from October to November 2019. From the dry deposition samples, NH_4 and Ca were the ions with the greatest concentrations (Figure 4a). In terms of deposition, ammonium was higher than any other ion in both dry and wet cases (Figures 4b and 4c). The pH of dew and frost from this research was much higher (more basic) than historical studies (Figure 5b). Most HYSPLIT trajectories showed air traveling from the northwest or Canada during the three days before collecting samples. Comparisons of ion concentrations and HYSPLIT models show that trajectories resembling a "backwards check" (Figures 6a and 6b) had the highest number of ions and organic acids present at higher concentrations while trajectories of air parcels that travel over the Atlantic Ocean (Figures 6c and 6d) have fewer ions and organic acids present.

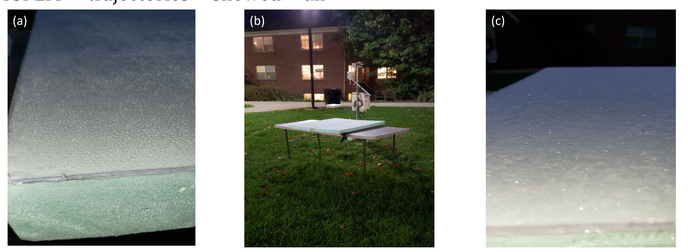

Figure 7: Surface of the collector with dew before collection (a), table with collector clamped onto it (b), and collector surface with frost before collection (c).

Conclusions and Future Work

For this research, dry deposition to a liquid or icy surface was studied through collection and measurement of chemical concentrations and pH. The most common ions in dry deposition field samples were NH_4, Ca, and NO_3. Dry deposition of NO_3 and SO_4 has decreased since 1992 while that of NH_4 has remained stagnant (Figure 5a). The sources of these chemicals generally were in the Northwest U.S. or Canada 72 hours before collection, but concentrations trends were hard to correlate with geographical trends of the trajectories. Wet deposition had a higher removal rate of chemicals than dry deposition, but the latter is effective in removing NH_4 and Ca.

For future research, more samples taken over a timespan longer than five weeks would be beneficial to better understand concentration trends. A statistical method to quantify the trajectory data would also be useful to attribute concentration trends to source regions more accurately.

References

Pierson, W.R., Brachaczek, W.W., Gorse, R.A., Japar, S. M., & Norbek, J. M. (1986). On the acidity of dew. *Journal of Geophysical Research, 91* (D3), 4083-4096.

Wagner, G. H., Steele, K. F., & Peden, M. E. (1992). Dew and frost chemistry at a midcontinent site, United States. *Journal of Geophysical Research, 97* (D18), 20591. doi: 10.1029/92jd02385

Acknowledgements

I would like to thank the Earth and Environmental Sciences department at Susquehanna University for being supportive of my education. Specifically, I'd like to thank Dr. Derek Straub for advising me on this project. I'm dedicating this research to my mother, who couldn't see this for herself but would have been proud of me anyway.